Northern Hemisphere Cyclone Trends in Reanalysis Data

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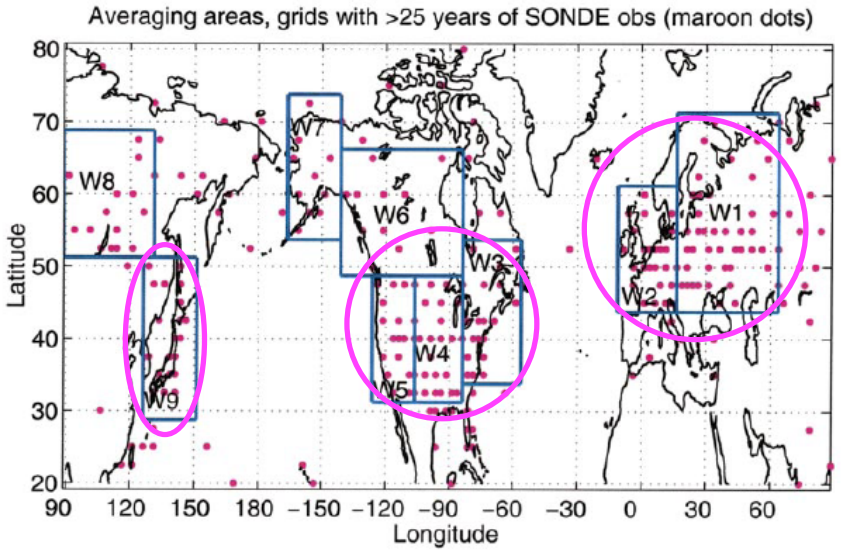
SoMAS
School of Marine and Atmospheric Sciences

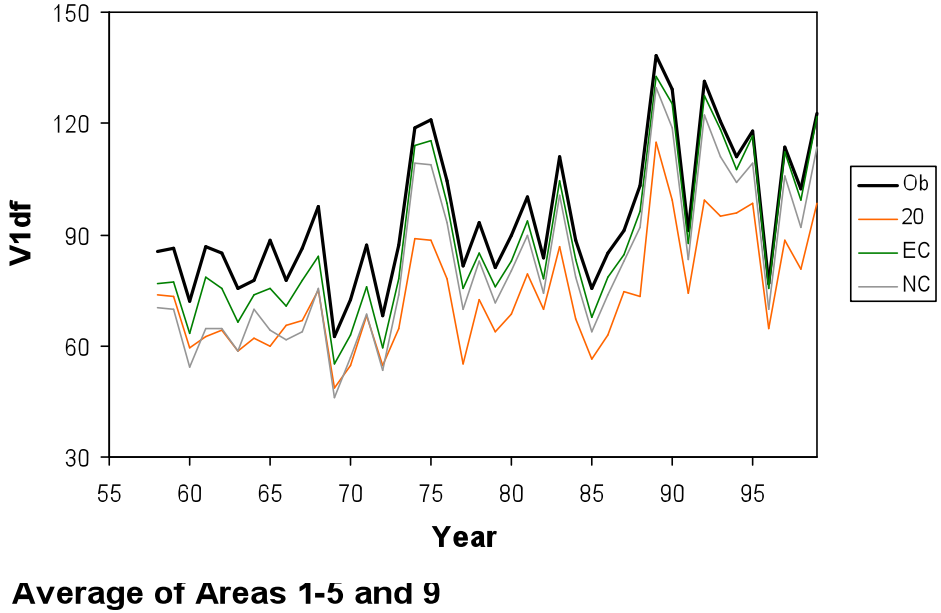
- Research funded by NOAA Project:
  - Assessing the Quality of Synoptic Scale Variability Derived from the 20th Century Reanalysis Project

Motivation

- Several studies have suggested that NH storm track activity has increased between 1950 and 1999, mostly based on NCEP-NCAR reanalysis data:
  - Graham and Diaz (2001): Pacific cyclone activity
  - Geng and Sugi (2001): Atlantic variance statistics
  - Chang and Fu (2002): NH variance statistics
- However, more recent studies have suggested that NCEP-NCAR and ERA40 may have spurious trends due to change in observing system
  - Harnik and Chang (2003): Compared NCEP-NCAR reanalysis to rawinsonde observations
  - Chang (2007): Compared NCEP-NCAR and ERA40 reanalyses to ship observations
  - Bengtsson et al. (2004): Spurious jumps in kinetic energy in ERA40 in the 1970s due to introduction of satellite data
- NOAA's 20th Century reanalysis, using surface obs only, is expected to contain less of a spurious trend

- Previous webinar (2/14/2012):
  - Examined upper tropospheric trends in variance of 300 hPa *v'*
  - Compared to variance computed directly from rawinsonde observations
  - Results:
    - Over regions with rawinsonde observations, trends derived from 20Cv2 most consistent with those derived from observation, even though rawinsonde observations are not assimilated into 20Cv2
    - Trend in Pacific derived from 20Cv2 much lower than those derived from NNR or ERA40



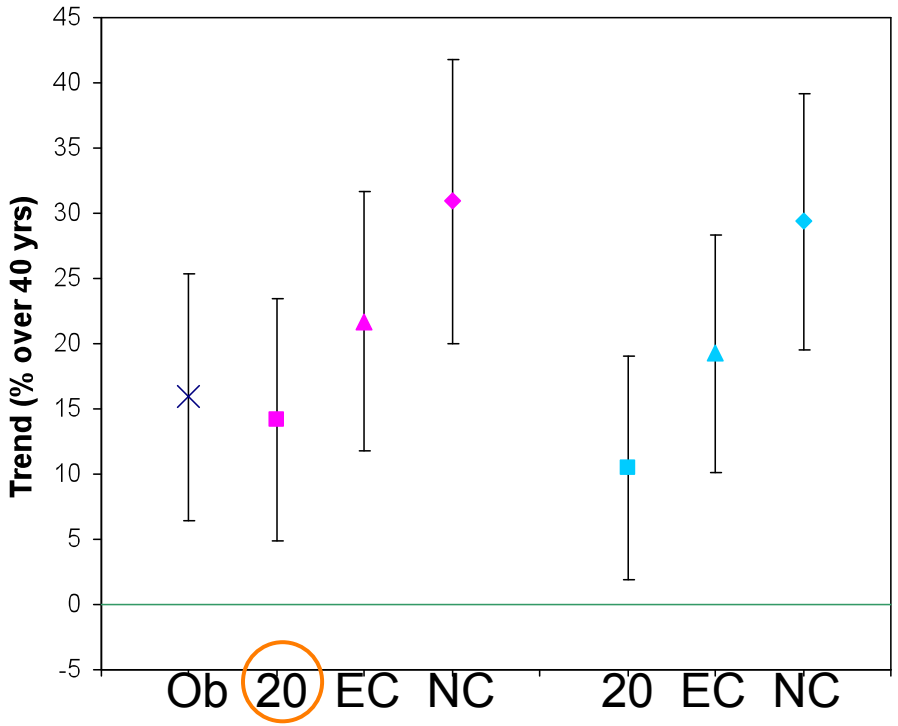


Average of Areas 1-5 and 9

×: Observations

Magenta: REAN filtered by Obs

Cyan: Full REAN

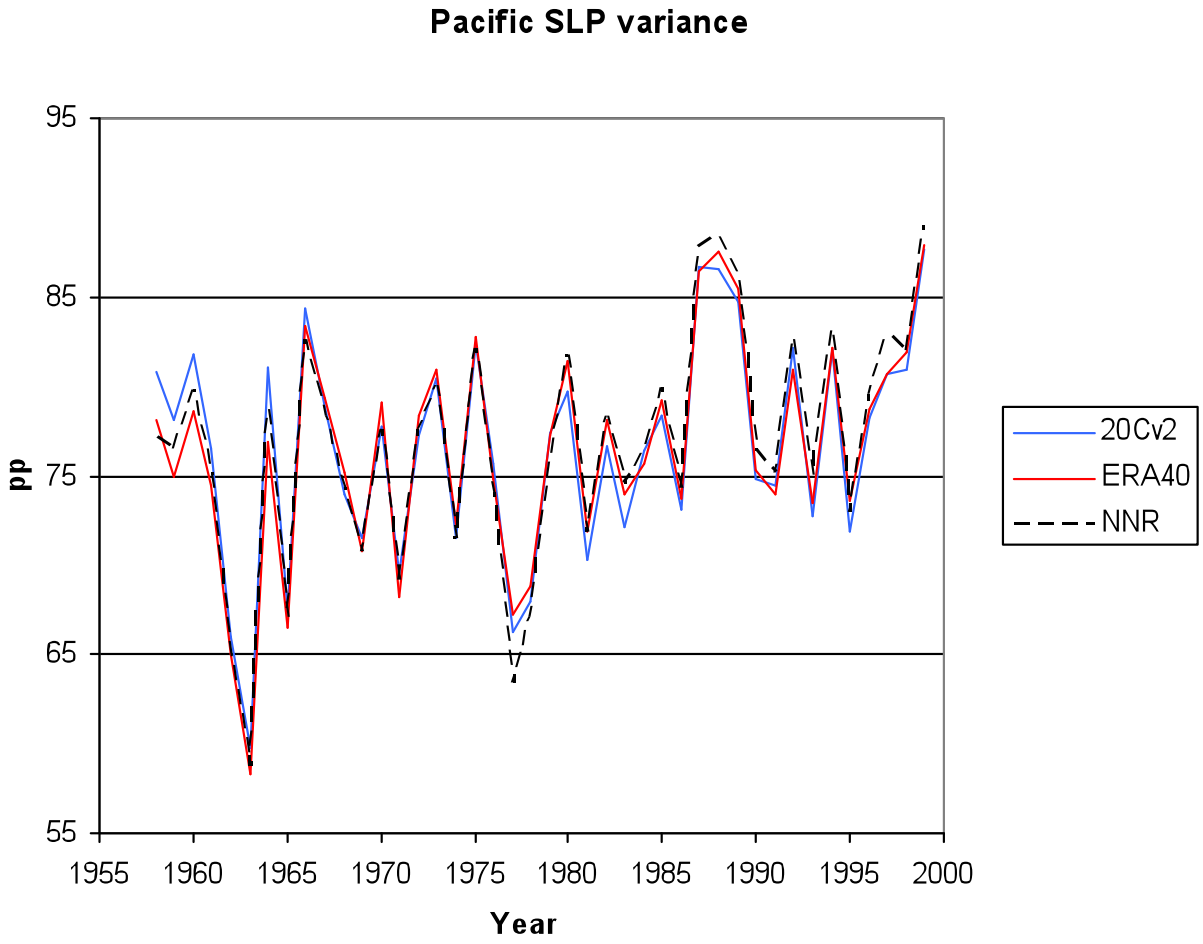


Further Analyses

- How do these biases impact surface cyclone statistics?

- Data: 6-hourly SLP data from 20Cv2, ERA40, and NCEP-NCAR reanalysis, DJF 1958-2001

- First, examine SLP variance statistics
  - Chang (2007) compared trends in SLP variance derived from NCEP-NCAR and ERA40 to ship observations
    - Trend in Pacific storm track activity based on ship observations ~20-60% of that found in NCEP-NCAR and ERA40
    - Trend in Atlantic more consistent – more ship observations?
    - How about 20Cv2?

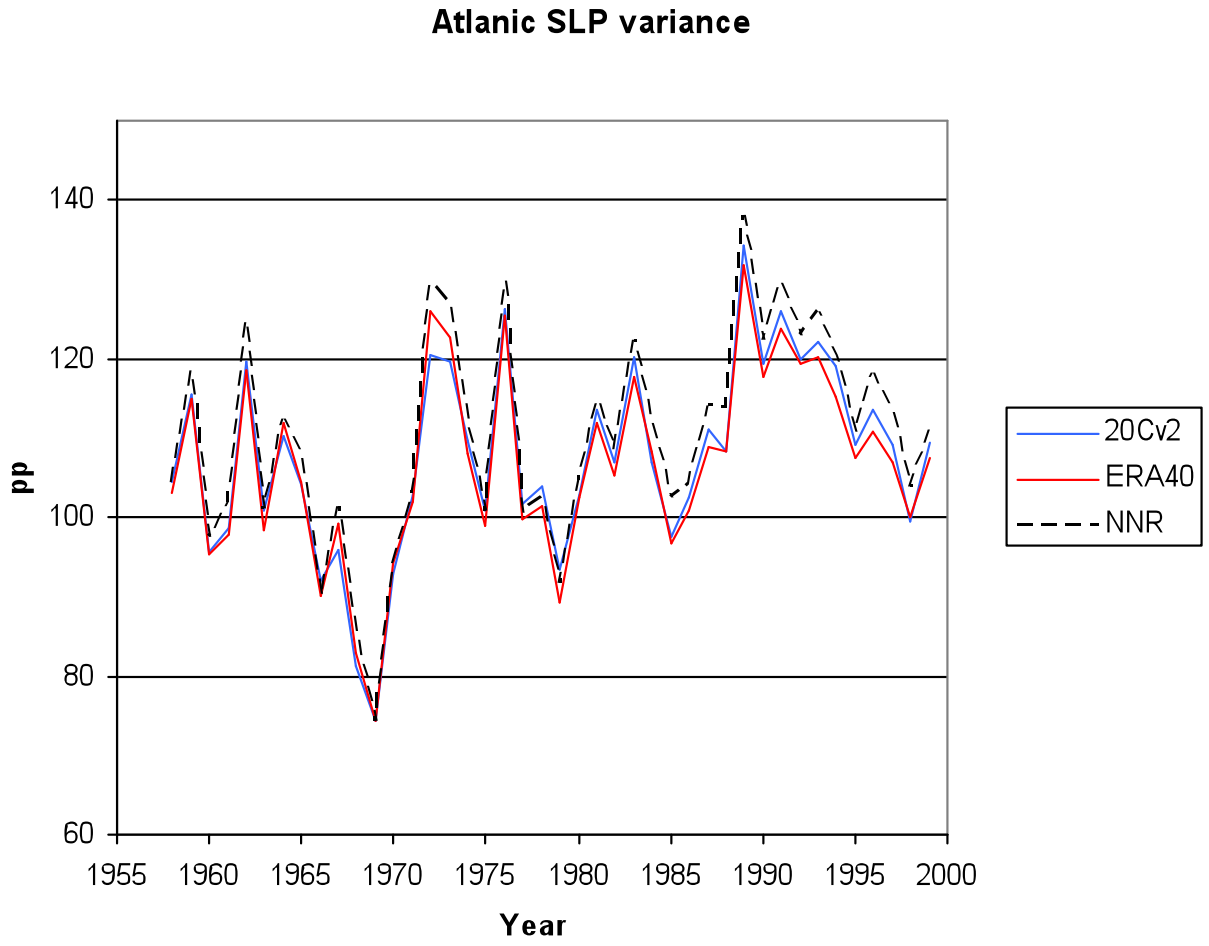


Pacific Trend: (41 years)

20Cv2: 7.7 ± 8.3% Not significant at 95% level

ERA40: 11.3 ± 8.3%

NNR: 12.8 ± 7.9%



Atlantic Trend: (41 years)

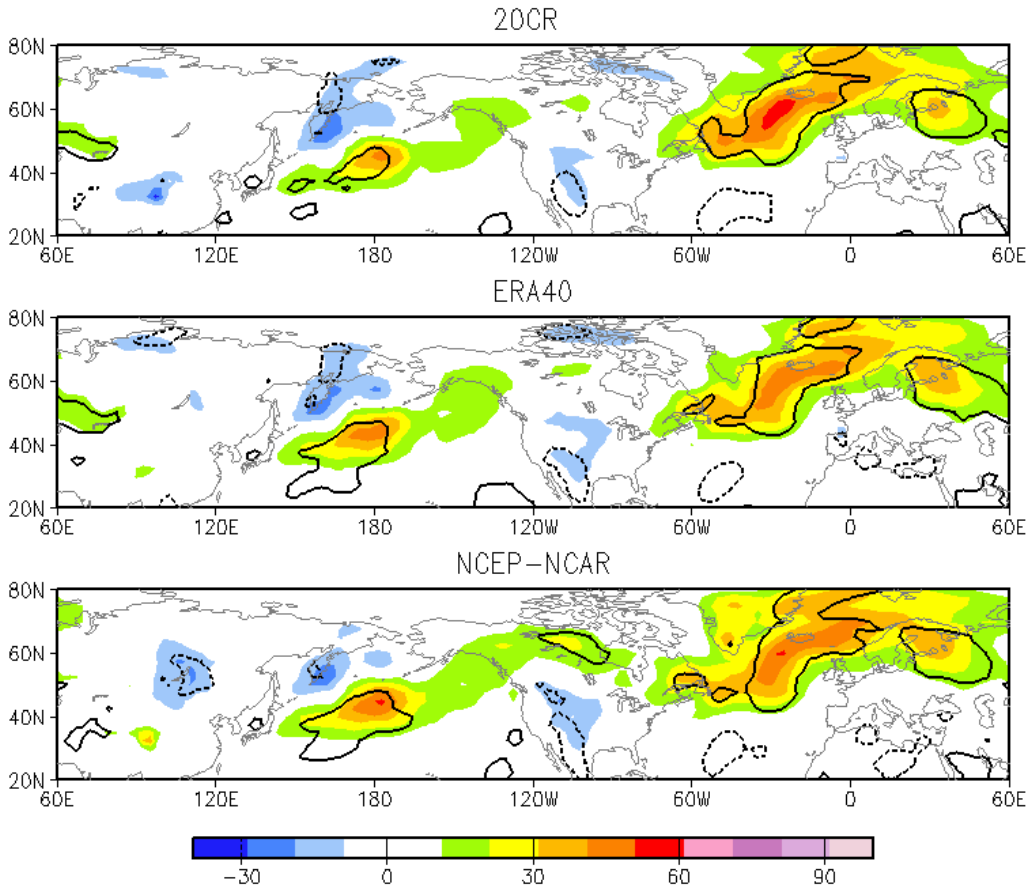
20Cv2: 14.4 ± 11.1%

ERA40: 12.4 ± 11.3%

NNR: 15.2 ± 11.9%

Difference between 1989/90-98/99 and 1959/60-68/69

SLP variance (hPa^2)



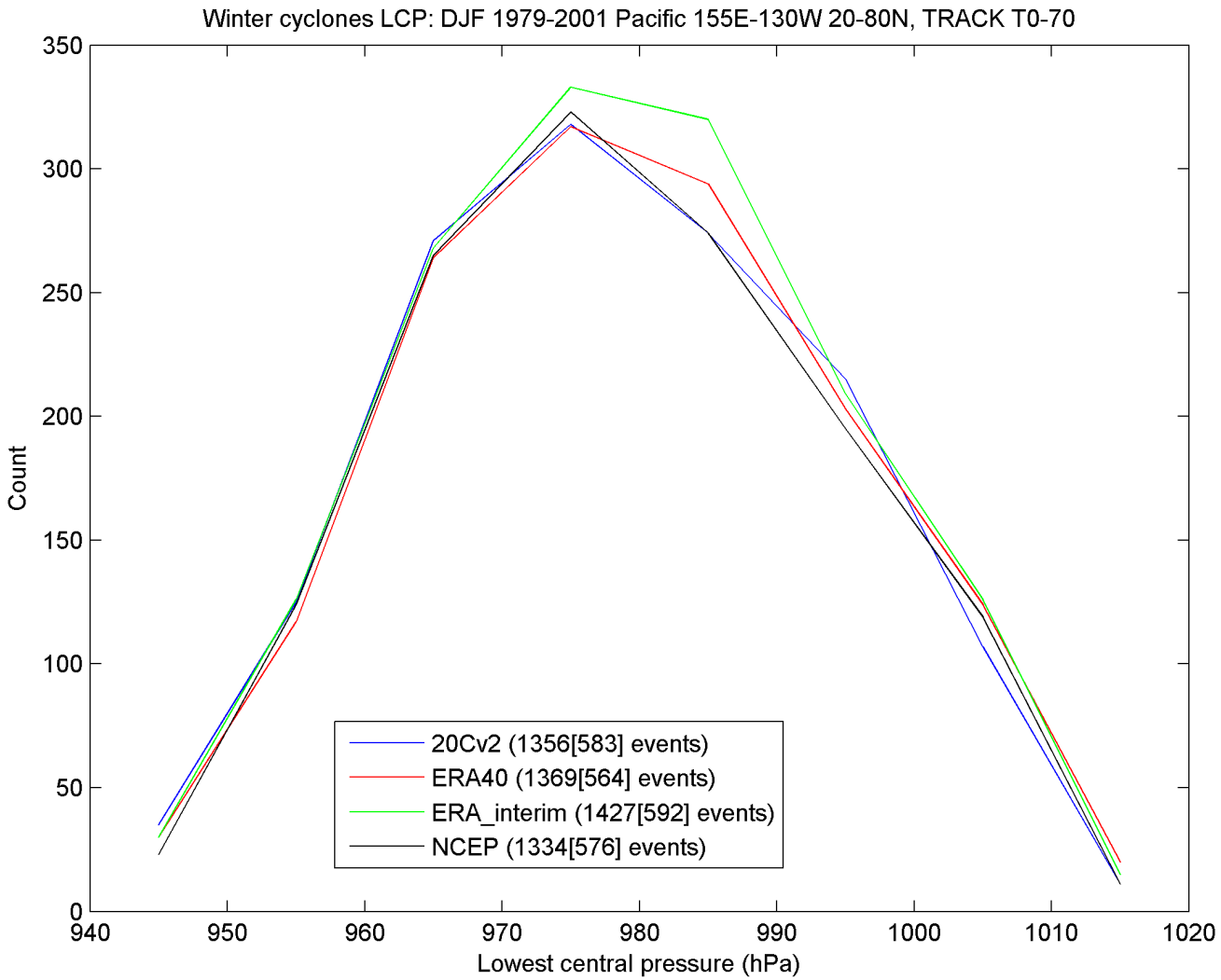
Contours: 95% significance

- Pacific trend in SLP variance in 20Cv2 ~60% of that in NCEP-NCAR
  - More consistent with trend estimated based on ship observations (Chang 2007)
- Atlantic trend more consistent between the 3 reanalysis datasets

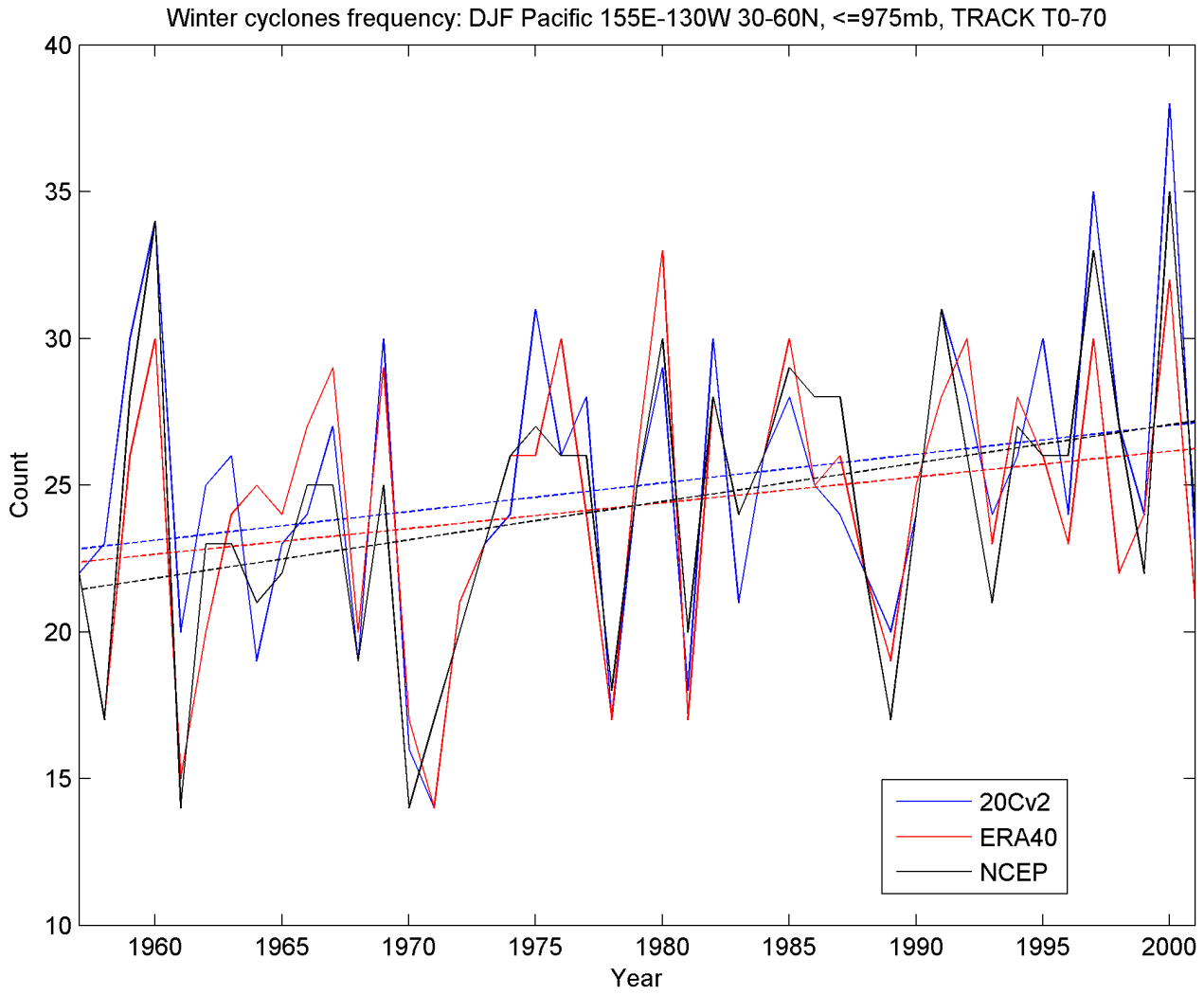
Cyclone Track Statistics

- Methodology
  - Feature tracking algorithm developed by Hodges (1994, 1995, 1999)
  - Tracked:
    - Total SLP
    - Filtered SLP – filtered to keep spatial scales of T5-T70
    - Keep only cyclones lasting over 2 days and traveling over 1000 km

Cyclone Count as a Function of Minimum Pressure
Pacific DJF 1979-2001



Pacific # of cyclones deeper than 975 hPa

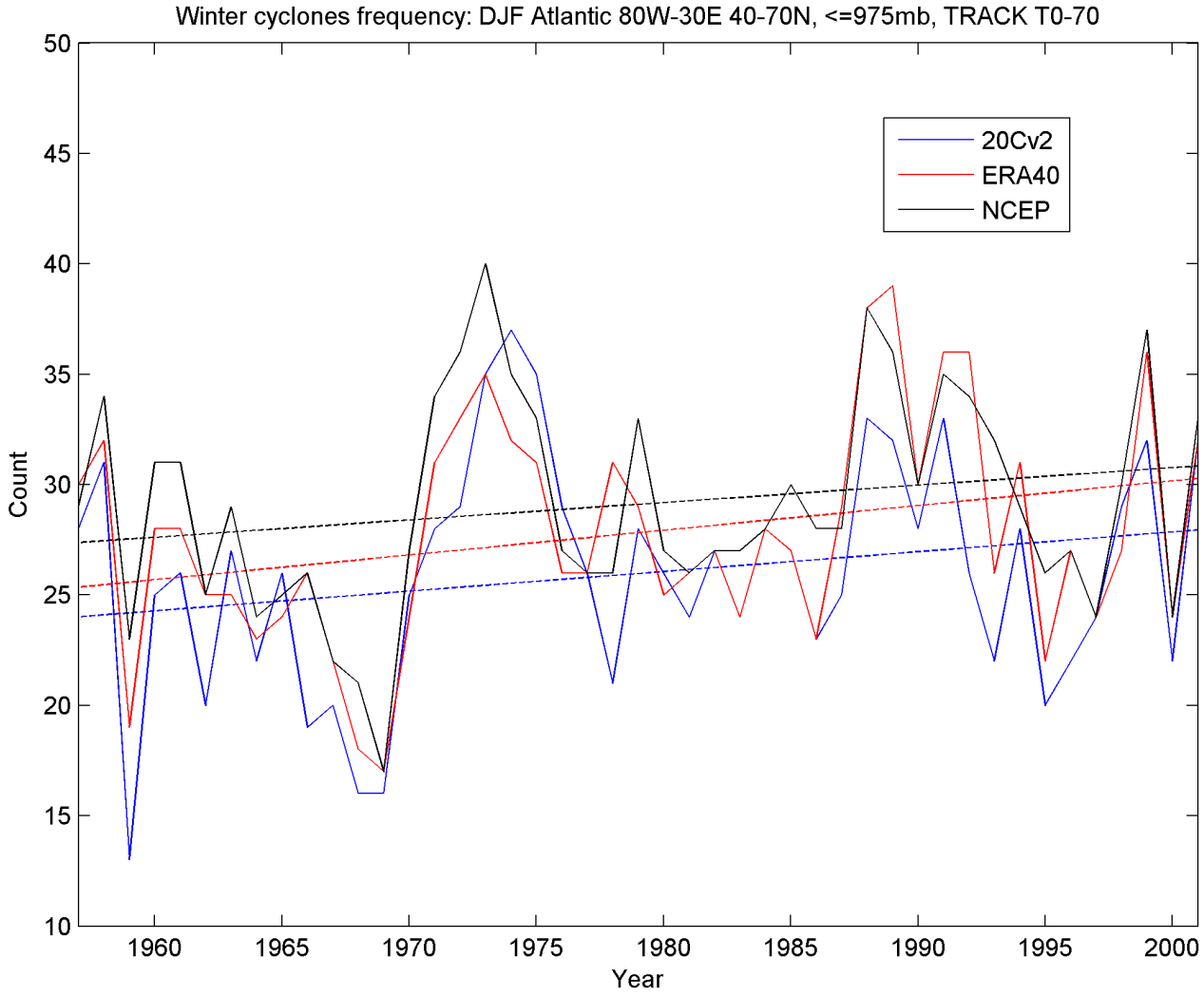


Pacific Trend:
1957/58-2001/02

20Cv2: 4.3 ± 4.9
ERA40: 3.9 ± 4.6
NNR: 5.8 ± 4.6

Not significant at 95% level

Atlantic # of cyclones deeper than 975 hPa



Atlantic Trend:
1957/58-2001/02

20Cv2: 3.9 ± 5.3
ERA40: 4.9 ± 5.0
NNR: 3.5 ± 4.9

Not significant at 95% level

Discussions

Inconsistencies Between the Different Trends?

Percentage trend over 41 years (1957/58 – 1998/99)

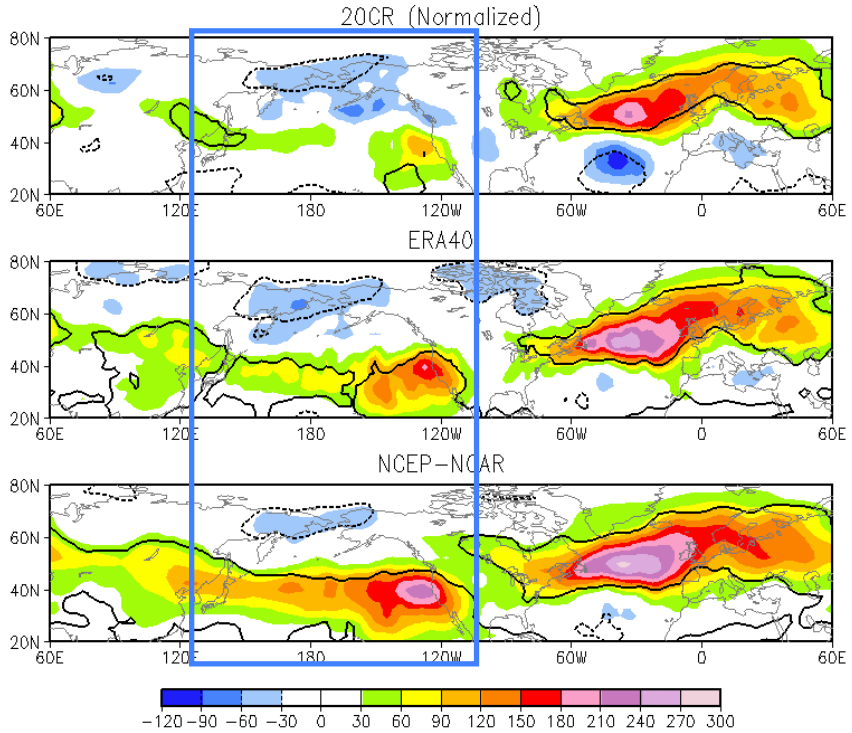
	# Pacific deep low*	Pacific pp	Pacific vv300	# Atlantic deep low	Atlantic pp	Atlantic vv300
20Cv2	17%	7.7%	2.6%	15%	14.4%	13.4%
ERA40	16%	11.3%	13.0%	18%	12.4%	20.9%
NNR	24%	12.8%	29.4%	12%	15.2%	30.0%

*: < 975hPa

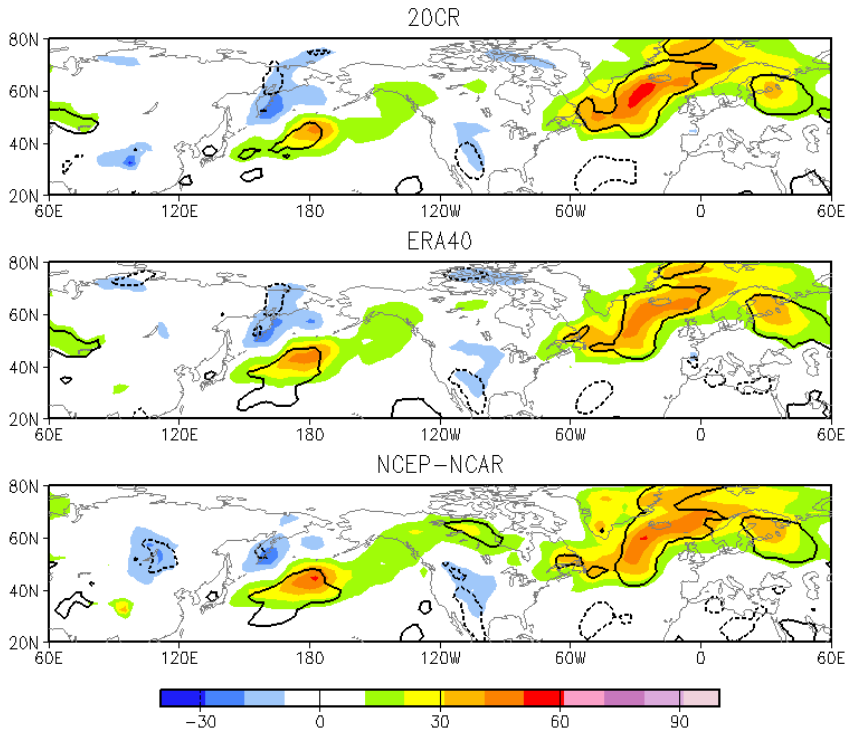
Not significant at 95% level

Difference between 1989/90-98/99 and 1959/60-68/69

300 hPa v' variance (m^2s^{-2})



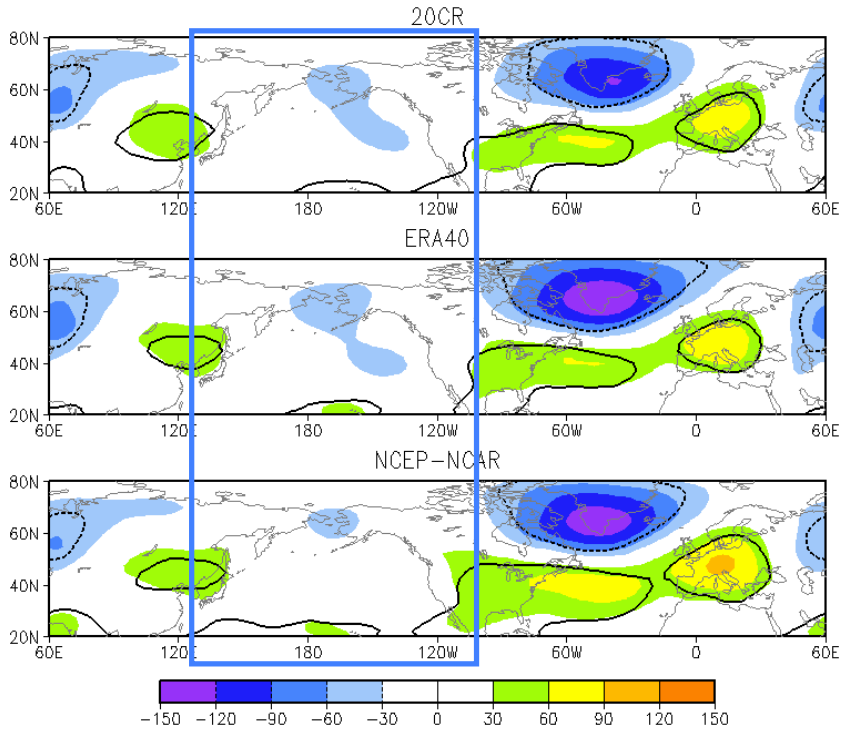
SLP variance (hPa^2)



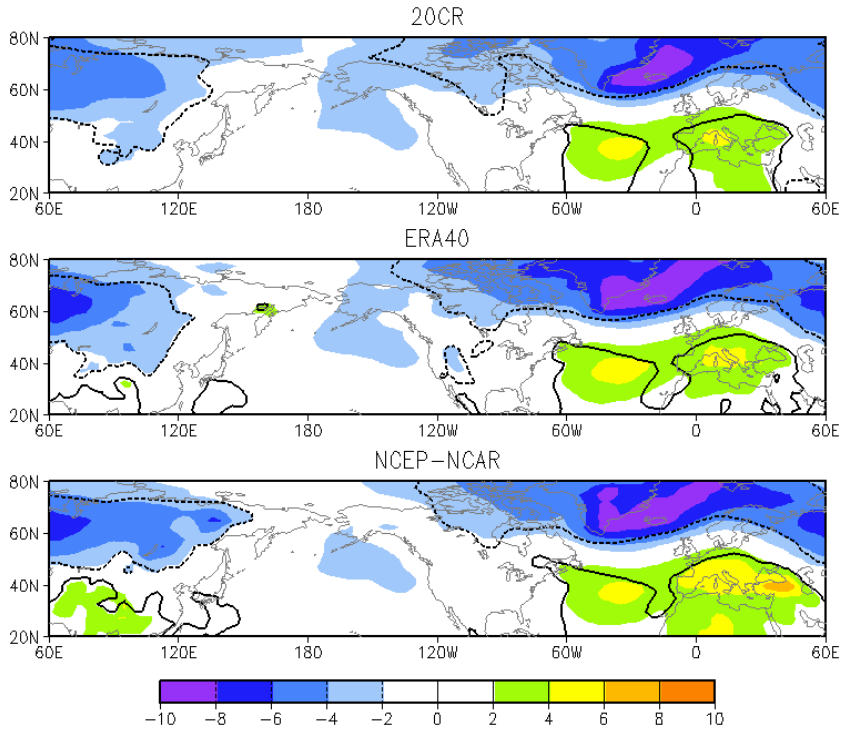
Contours: 95% significance

Difference between 1989/90-98/99 and 1959/60-68/69

300 hPa Z mean (m)



SLP mean (hPa)

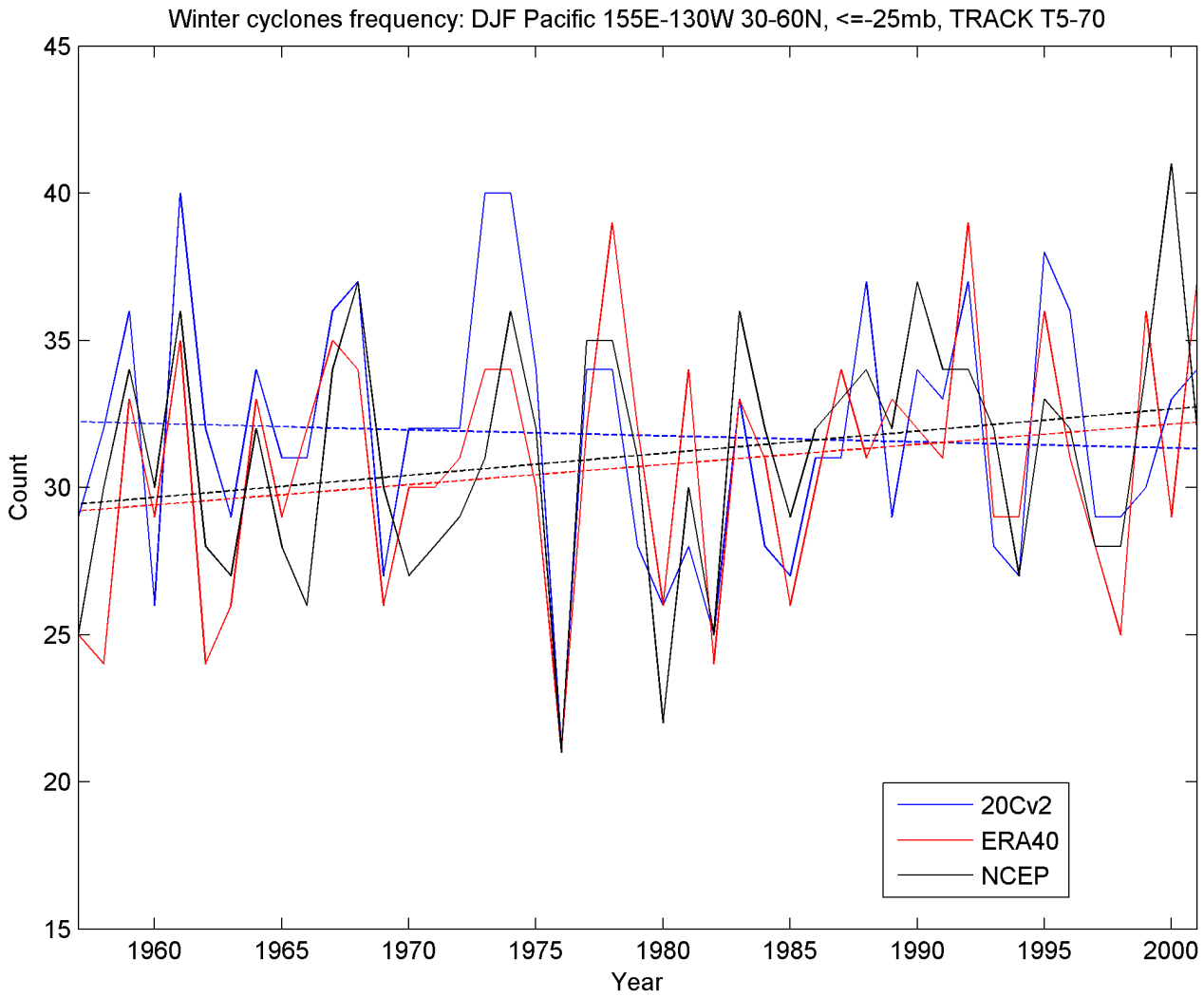


Contours: 95% significance

Discussions

- Significant mean flow change over Atlantic
  - Consistent with significant storm track change
- Very little mean flow change over Pacific
  - Inconsistent with large storm track change
- Large change in number of deep cyclones (< 975 hPa) over Pacific
  - Perhaps in part due to trend in SLP?
    - Mean SLP decreased by ~3 hPa between 1960's and 1990's near the Aleutians

- Cyclones defined by removing seasonal mean and large spatial scale (retained scale: T5-T70)
- # deep cyclones (< -25 hPa) in Pacific



Pacific Trend (1957/58-2001/02):

20Cv2: -0.9 ± 4.4
ERA40: +3.0 ± 4.2
NNR: +3.3 ± 4.1

Not significant at 95% level

Conclusions

- Trends in NH winter storm track activity from 1957/58 to 1998/99 have been compared between 20C, NNR, and ERA40 reanalyses
  - In terms of 300 hPa *v'* variance, SLP variance, and surface cyclone statistics
    - Atlantic trend largely consistent, except NNR trend in 300 hPa *v'* variance is much larger and is likely biased high
      - Also consistent with significant trend in mean flow over Atlantic
    - For Pacific, 20C reanalysis does not show a significant trend in any of the storm track quantities examined
      - Over regions with observations, trends derived from 20C reanalysis most consistent with those derived directly from observations (rawinsonde and ship)
      - Very little trend in mean flow over Pacific, inconsistent with significant trend in storm track activity in NNR and ERA40
    - Upper level trend more biased in NNR and ERA40 likely because of increasing number of aircraft and satellite observations from late 1960s through late 1970s